# SIMULATIONS OF ATMOSPHERIC DYNAMICS AND CLOUDINESS IN A COASTAL REGION

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## LONG TERM GOALS

The goal of this project is to increase understanding of the modification of the complex atmospheric dynamics and thermodynamics due to the interaction of air, sea, and land in a coastal region. This increased understanding will improve forecasting of coastal weather on a wide spectrum of spatial and temporal scales.

## OBJECTIVES

Specific project objectives include: 1) investigating the structure and evolution of a low-level jet over the coastal waters as well as jet modification by thermal and topographic effects, stability and turbulence transfer, and cloud-driven processes; 2) investigating the main determinants for the development of local circulations including land-sea breezes; 3) developing conceptual and operational models for improved prediction of fog and clouds over the coastal waters; and 4) improving the predictability of the coastally-trapped disturbances and southerly surges. The project is supported by the Office of Naval Research, Marine Meteorology and Atmospheric Effects.

## APPROACH

The proposed approach involved the use of selected atmospheric models and measurements from routine observations (surface stations, buoy), remote sensing instruments (wind profilers), and special field program aircraft (Coastal Waves 96). Mesoscale Model 5 (MM5) was utilized for short- and long-term numerical simulations of atmospheric processes over the U.S. California coast. The model grid encompassed the coastal area from north of Cape Mendocino to the Los Angeles basin. We also have developed a parameterization of turbulence kinetic energy and turbulence fluxes linked to the MM5 results (Koračin et al. 1997b).

## WORK COMPLETED

We performed a numerical experiment simulating hourly atmospheric dynamics over the U.S. California coast for all of June and July 1996 with a high horizontal (9 km) and vertical resolution (35 levels). The model domain was 900 km x 900 km x 15 km. Model simulation results were stored in hourly intervals. The major task prior to interpreting the simulation results was to evaluate the

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model by using aircraft, radiosonde, and wind profiler data (Bodega Bay, Fort Ord, Piedras Blanco, and Point Arena). The model results closely correlated with field measurements. Preliminary model evaluation was reported in Koračin et al. (1997a, 1997b, website 1). Fig. 1 shows a time series of the measured and simulated wind speed and direction at Point Arena at the 300 m level. Close agreement is apparent for time variation, mean value, and standard deviation of wind speed. Similar results were obtained for Fort Ord. Many computer programs were created for numerical analysis as well as graphical presentation of the model results, including animation. In the first processing step, we averaged wind components, temperature, and humidity over daily intervals to use as the basic input for analyzing the simulations.

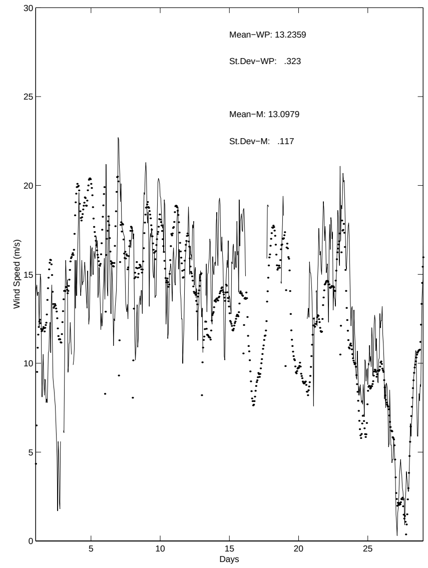


**Figure 1** Measured vs. simulated wind speed at 300 m AGL at Point Arena for all of June 1996.

## RESULTS

Most previous modeling studies of west coast weather phenomena (Low-Level Jets (LLJ), land-sea breezes, cloudiness) have focused on either idealized conditions or several-day cases. The results of this thoroughly evaluated model provide an excellent database for investigation of coastal weather phenomena over much longer time periods and at high vertical and horizontal resolution. The simulation results indicated that, on average, the largest coastal jet is expected between 200 and 400 m ASL and mainly in terms of local maxima (Koračin et al. 1997b). The strongest winds were

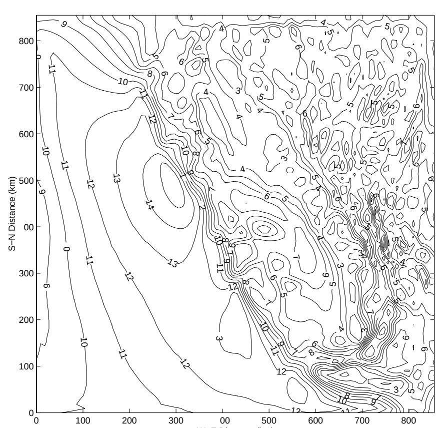


**Figure 2.** Contour plot of average hourly wind speed at 277 meters as simulated by MM5 for all of June 1996.

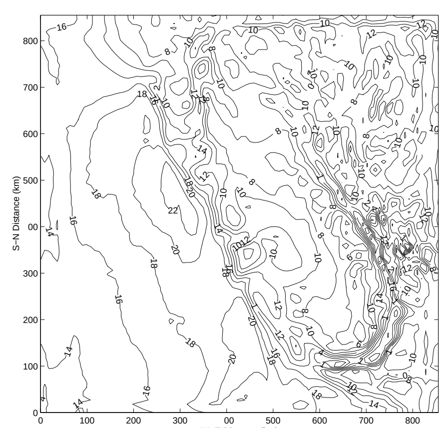


**Figure 3.** Same as Figure 2, except maximum hourly wind speed.

predicted in the Point Arena and Big Sur areas. Figs. 2 and 3 show contour plots of average and maximum wind speed over the California coast as simulated by the model at the 277 m ASL level and averaged over all hourly intervals in June 1996. Even in a monthly average, the significant local maxima are clearly visible. The average predicted winds were in excess of 10 $ms^{-1}$ in the wide belt of approximately 200 km extending from the coast offshore.

In order to study the effect of cloudiness on the jet, we selected ten days with mainly clear skies and ten days with cloudy conditions (Koračin et al. 1997b). The vertical profiles of wind speed as averaged for all hours in June 1996 are shown in Fig. 4. The wind speed profiles for the clear-sky and cloudy conditions, respectively, are also plotted in the same figure. Cloud-driven processes induced turbulent mixing and associated efficient transfer of momentum, and the jet became less stratified and weaker. On the other hand, the marine atmospheric boundary layer was more stable during the clear-sky cases, which enhanced jet stratification and magnitude. The differences in averaged wind speed between clear-sky and cloudy cases were approximately 5 $ms^{-1}$.

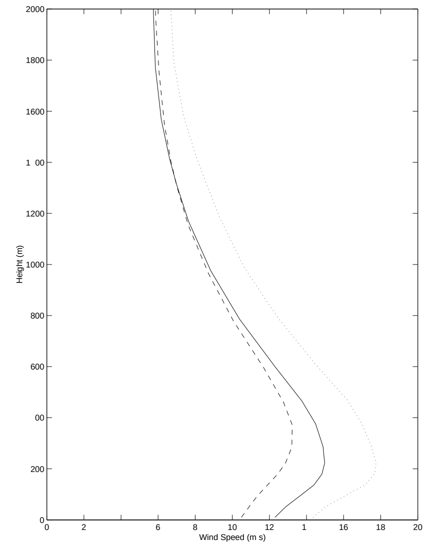

**Figure 4.** Vertical profile of simulated wind speed at Point Arena averaged for all of June 1996. (solid: all days; dashed: cloudy days; dotted: clear-sky days)

Leipper and Koračin (1997) investigated the importance of occasional hot spell events on different coastal weather phenomena, particularly the formation and evolution of coastal fog and stratus clouds. They hypothesized that only when the warm inland flow is further heated by adiabatic effects of the downslope flow does the coastal air become stable enough to initiate or facilitate the evolution of a fog sequence. They also performed numerical simulations using idealized radiosonde data as an input to a 1D higher-order closure model (Koračin and Rogers 1990, Rogers and Koračin 1992). The fog was first simulated in the moist and cool shallow marine layer, and evolution was significantly determined by radiative processes and the generation of turbulence within the fog layer. On the second day, the fog penetrated into the hot air layer, after which growth was faster due to turbulent transport of near-surface moisture and cooling effects.

## IMPACT

The results of this study improve the predictability of wind, turbulence, clouds, and fog in coastal areas. This will aid in decision making and in the performance of low-level airborne and sea-based naval operations. The results may be applied to other coastal areas worldwide.

## TRANSITIONS

NPS expressed interest in using the hourly MM5 wind fields developed by this study to drive the Princeton ocean model (Dr. Le Ly). NCAR invited DRI to run the same area for the upcoming field program at the Vandenberg base, and NCEP invited us to participate in ETA model development. We are also planning to compare navy and public-type models as well as to enhance forecasting techniques at the NWS offices through the use of numerical simulations.

## RELATED PROJECTS

We collaborate with Drs. Wendell Nuss and Le Ly (NPS, Monterey), Dr. David P. Rogers (Scripps, San Diego), and Dr. Michael Tjernström (Uppsala University, Sweden), all of whom have ONR funding. We collaborate with Dr. Dale Leipper on a NWS project to operationally test his system for forecasting fog at the Monterey Bay airport. The P.I. for this project, Dr. Koračin, has another ONR funded project (N00014-96-1-1235), which focuses on turbulence transfer over inhomogeneous surfaces (website 2) and was also applied to the evolution of marine clouds. He has also conducted a modeling study related to a future airport siting near Las Vegas (website 3) as well as other studies of transport and dispersion of pollutants using the MM5 model (websites 4,5).

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Website 1: http://www.dri.edu/ResearchAreas/Modeling/cjet.html
Website 2: http://www.dri.edu/ResearchAreas/Modeling/newmod.html
Website 3: http://www.dri.edu/ResearchAreas/Modeling/vegasair.html
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Website 5: http://www.dri.edu/ResearchAreas/Modeling/wmod.html